

A brush fire forensic case

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In Italy, every summer forest fires attract public attention due to the number of victims, the intensity of the fires, the areas devastated, the environmental damage and the loss of property. Excluding some fires by natural causes, other causes are related to the social, economic, and productive profile of the territory. The erroneous expectation is that wooded areas destroyed by fire can then be used for private interests. Often, a fire, started to clear a small area, can completely change the expected result, producing disaster, loss of property, destruction of entire forests and resident fauna, and kill innocent people. In this case report, the reconstruction of an arson scene, the analytical techniques and the results obtained are illustrated in this paper, with the aim of sharing with other research laboratories the current knowledge on forest fire.

En Italie, chaque été, les feux de forêts attirent l'attention du public, à cause du nombre des victimes, de l'intensité des feux, des domaines dévastés, des dommages environnementaux et de la perte de propriétés. En excluant certains feux dus à des causes naturelles, d'autres causes sont liées au profil social, économique et productif du territoire. Il est faussement attendu que des régions forestières détruites par le feu puissent ensuite être utilisées pour des intérêts privés. Souvent un feu utilisé pour nettoyer une petite surface peut changer complètement le résultat attendu, produisant un désastre, une perte de propriété, la destruction de forêts entières et de la faune résidente et tuer des gens innocents. Dans ce cas, la reconstruction d'une scène d'un incendie criminel, les techniques analytiques et les résultats obtenus sont illustrés dans cet article afin de partager, avec d'autres laboratoires de recherche, les connaissances actuelles sur les feux de forêts.

In Italien ziehen jeden Sommer Waldbrände – bedingt durch die Zahl der Opfer, die Intensität der Feuer, der Größe der verwüsteten Flächen, den Umweltschäden und dem Verlust von Eigentum – die Aufmerksamkeit der Öffentlichkeit auf sich. Betrachtet man nur die nicht natürlichen Ursachen, so hängen diese mit den sozialen und wirtschaftlichen Verhältnissen in den betroffenen Landstrichen zusammen. Es existiert nämlich die irrige Annahme, das vormalig bewaldete, durch Feuer zerstörte Flächen nun für private Zwecke genutzt werden könnten. Oft aber kann ein Feuer, das zur Rodung einer kleinen Fläche gelegt wurde, zu einem so nicht erwarteten Ergebnis führen – einem Desaster, dem Verlust von Eigentum, der Zerstörung ganzer Wälder mit der dort lebenden Fauna oder gar dem Tod unschuldiger Menschen. In diesem Fallbericht werden der Vorgang einer Brandstiftung rekonstruiert und die analytischen Techniken sowie die damit erzielten Ergebnisse beschrieben. Ziel ist es, das aktuelle Wissen über Waldbrände mit anderen Forschungslaboratorien zu teilen.

En Italia cada verano el incendio de bosques atrae la atención pública debido al número de víctimas, la intensidad del fuego, las áreas devastadas, el daño medioambiental y la pérdida de propiedades. Si se excluyen algunos incendios por causas naturales, otras causas están relacionadas con el perfil social, económico y productivo del territorio. A menudo, un fuego que se ha empezado para limpiar una pequeña zona, puede cambiar completamente el resultado esperado produciendo desastre, pérdida de propiedades destrucción de bosques completos y fauna residente y matar gente inocente. En este caso que se publica se ilustra la reconstrucción de un incendio provocado, las técnicas analíticas y los resultados obtenidos con el fin de compartir con otros laboratorios de investigación los conocimientos actuales sobre incendios de bosques.

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Introduction

A forest fire can be a real ecological disaster, regardless of whether it is caused by natural forces or human activity. It is impossible to control nature, but it is possible to reduce the risk of forest fire and thereby minimise their frequency. Anticipation of factors influencing the occurrence of fire and understanding the dynamic behaviour of fire are critical aspects of fire management.

Forest fires across Europe during the summer of 2003 attracted public attention due to the number of victims, the intensity of the fires, the areas devastated, the environmental damage and the loss of property. Fire risk reached unusually high levels as a direct consequence of the summer's extreme weather conditions: heat and drought over long periods.

At the time of writing it is too early to analyse in depth the damages of the 2003 fire season. However, in some European countries the area consumed by fire is already much larger than the average area recorded during the last decade. Some relevant data, as yet approximate and not validated, estimate that 417,000 hectares of forest have been destroyed by fires in Portugal, 54,000 in France and about 100,000 in Spain.

The causes of the fires and the damage they produce vary widely and are both social and ecological in nature. Prevention and control strategies address public awareness, repression of crime, silvicultural cleaning measures to reduce the fuel load and economic incentives for appropriate management measures, as well as effective fire suppression. In all cases, hot and dry weather conditions can make the severity of fires much worse. The existence of habitations in endangered areas complicates the task of fire fighters and increases damage to property.

Five categories of causes may be taken into consideration: natural fires, accidents, negligence, arson, and fires of dubious cause. Excluding the natural fires, all other causes are strictly related to the social, economic and productive profile of the territory.

In July 2003 in the south-east of France, tragically, five people including four tourists, died as a result of blazes. In September 2003, three firemen were killed while fighting a forest fire in the south of France, they were in a vehicle that was encircled by flames.

In Italy, in 2002 there were 4,382 fires involving a surface area of 40,235 hectares. Up to the end of summer 2003, 11,250 fires had destroyed a surface area of 84,347 hectares with an increment of 156.7% and 102.0% respectively. Arson is the main cause of forest fires in Italy and directly correlated to an increase in the number of fires in recent years. Some fires are set deliberately to destroy woodland which can then be used for private interests.

In August 2003, a hot south-west wind favoured the spread of many fires. In central Italy, a young woman was killed by fire and others were seriously injured. The woman, running away

from a brush fire started close to her holiday farmhouse, was frightened by the blaze and confused by the smoke, took the wrong direction and in a short time the smoke and fire were all around blocking her escape. The fire investigators received a little information concerning the place where supposedly the fire started and there they collected five debris samples and two wire loops. There were no eye witnesses and no other elements were available for the investigation.

The laboratory accepted the job even though it was the first forest fire after a long series of fires on buildings and industries.

The available analytical techniques, (gas chromatography/mass spectrometry, GC/MS) for an accelerant search were applied to the debris samples [1–20]. The wire loops were analysed by scanning electron microscopy/energy dispersive spectroscopy (SEM/EDS) [21, 22]. The results obtained are presented here but we have left out some details that might compromise the ongoing forensic investigation.

The aim of this paper is to share all the collected data with other laboratories and investigators involved in this field so as to enrich the literature on forest fire investigation.

Materials and methods

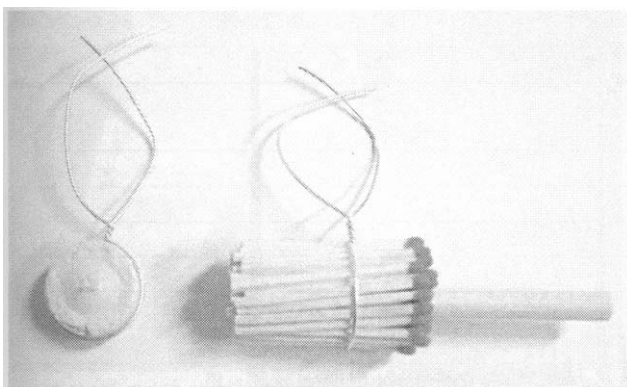
Samples and standards

The samples collected by the investigators were from the location where the fire supposedly started. Five of them were debris of the partially burned local vegetation. The two wire loops (Figure 1) were made of iron wire coiled to form a figure of 8. The closed rings were 2.5 cm in diameter and the open rings were different from the two wire loops. On the basis of previous experience, the investigators assumed that they might have been used as support for a time igniter to start the fire. The ignition materials mainly used for this kind of igniter were matches, together with cigarettes or sulphur tablets. Following the previous indication, two igniters were set up in the laboratory as reference for the spectroscopical analyses (Figure 2). The sulphur igniter (on the left side of Figure 2) was simply a sulphur tablet, with a diameter of 25 mm and 15 mm in thickness, supported by a wire loop. The sulphur tablets were widely available because they are used for sterilising wine barrels before use. The matches/cigarette igniter was made by putting about forty matches around the filter of a cigarette and held with a wire loop as shown on the right side of Figure 2.

Figure 1 Wire loop samples collected in the area where the fire supposedly started.



Figure 2 The sulphur and matches/cigarette igniters set up in laboratory.



A laboratory data bank of the most commonly-used flammable liquids was utilised for accelerant identification in the samples analysed by GC/MS [1, 12].

Accelerant extraction methods

Two extraction methods are habitually used to analyse fire debris. The extraction with a Solid Phase Micro-Extraction (SPME) [23–26] syringe was performed introducing the fibre into a 27 ml headspace vial containing an aliquot of debris sample. The vial was heated to 50°C for 30 min, allowing the volatile species to be released in the headspace and adsorbed on the PDMS fibre (100 µm). By introducing the syringe needle into a GC/MS injector, the system automatically performed the release of the adsorbed compounds, their gas chromatographic separation and mass spectrometric detection.

Using a Thermal Desorption Cold Trap Injector (TCT), an aliquot (100 mg) of fire debris was submitted to an on-line thermal desorption at 120°C x 4 min with cryofocusing of volatile compounds in the trap at –100°C. The successive quick heating of the trap to 250°C assured the transfer of volatile compounds into the GC/MS system for separation and identification of target compounds.

The choice of the extraction technique depended on the water content of each sample. Dry samples were usually analysed by TCT/GC/MS [1], for wet samples SPME/GC/MS was preferred. Particular samples were often analysed using both techniques.

GC/MS instrumentation and analytical conditions

All determinations were performed using a GC/MS system constituted by an HP 6890 Gas Chromatograph coupled with an HP 5973N Quadrupole. Chromatographic separation of the analytes was obtained by an HP 5MS capillary column with the following dimensions: length 30 m; internal diameter 0.25 mm and film thickness 0.25 µm. The column, with a constant helium flow of 0.7 mL/min, was submitted to the following temperature program: 40°C x 3 min; 10°C/min; 250°C x 15 min. The injector temperature was 250°C. All injections were performed in splitless conditions for 0.7 minutes. The mass spectrometer was in SCAN acquisition mode to detect the ions produced by

electron ionisation (70 eV) at 230°C ion source temperature, in the mass range from 50 to 300 Daltons, with a scan rate of 5.56 scan/sec.

Spectroscopic analysis

The SEM/EDS analyses were performed on a Philips XL40 scanning electron microscope equipped with a LaB₆ source. Using suitable detectors, the morphology and elemental composition of the samples were obtained. The system was coupled with an EDAX microanalysis probe able to detect atomic elements higher than sodium. Samples were analysed, without any preliminary treatment, ensuring the possibility of performing the same or other analyses in future.

Results and discussion

Two debris samples analysed by SPME/GC/MS gave positive results on accelerant research. Ion current at $m/z = 57$ was extracted from the total chromatogram [1, 9], the result is shown in Figure 3. The presence of a complete sequence of aliphatic hydrocarbons in the range C₁₀–C₂₁ is evident, with the characteristic peak distribution and the presence of the branched aliphatic hydrocarbons pristane and phytane typically present in the natural fuels. A sequence of unsaturated aliphatic hydrocarbons was also present, probably due to the combustion of plastic materials [20, 27–29] as a piece of polyethylene or polypropylene bags or tapes. No traces of plastic container were found in the area. An igniter device, found on a different forest fire, was made using a piece of tape to tighten the matches around a cigarette. However this might have originated as trash. There were no evidences of the presence of other accelerants. The hydrocarbon pattern observed may be attributed to diesel fuel as widely described by Bertsch et al [20]. In fact the chromatogram in Figure 3 shows ten consecutive aliphatic hydrocarbons against the necessary five for the described attribution; in addition pristane and phytane are also present.

The wire loop samples analysed by SEM/EDS showed the presence of particular stick structures on the metal surface. Their shape and the relative EDS analysis are shown in Figure 4. On

Figure 3 GC/MS analysis of a debris sample. The chromatogram is the result of the ion current extraction at $m/z = 57$ which is a diagnostic ion of the aliphatic hydrocarbons.

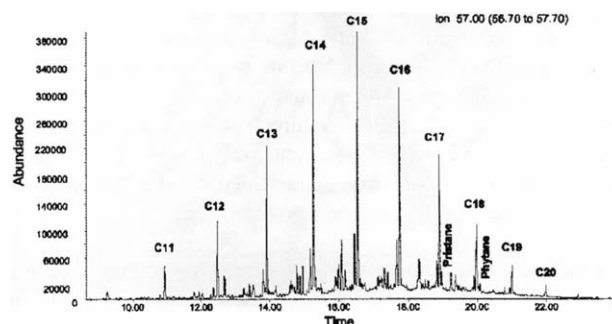


Figure 4 SEM/EDS analysis of the wire loop at the right side of Figure 1. On the left: micrograph of a stick structure on the metal surface. On the left: EDS analysis on the area inside square A.

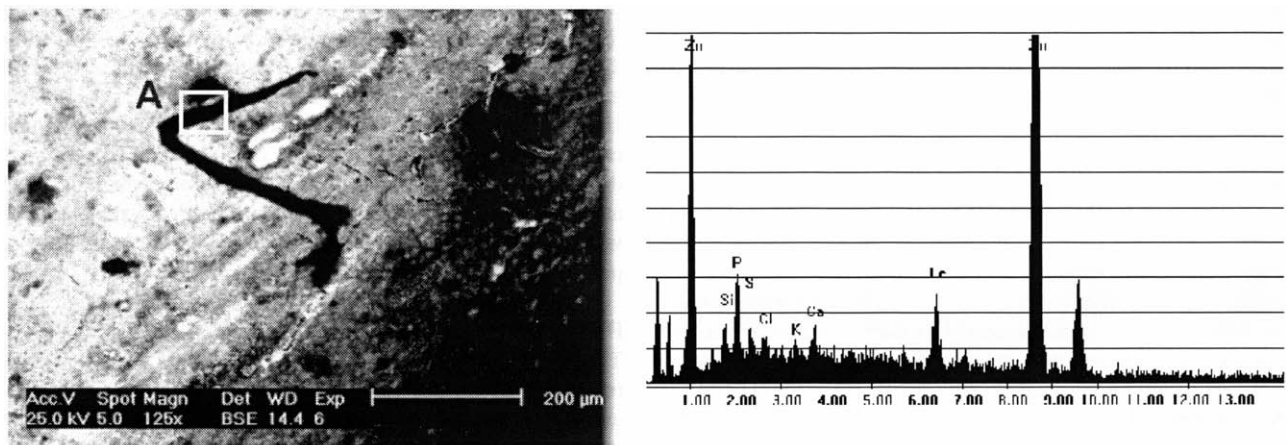


Figure 5 SEM/EDS analysis of the wire loop after burning of the sulphur igniter at the left side of Figure 2. On the left: micrograph of a spot structure on the metal surface. On the left: EDS analysis on the area inside square A.

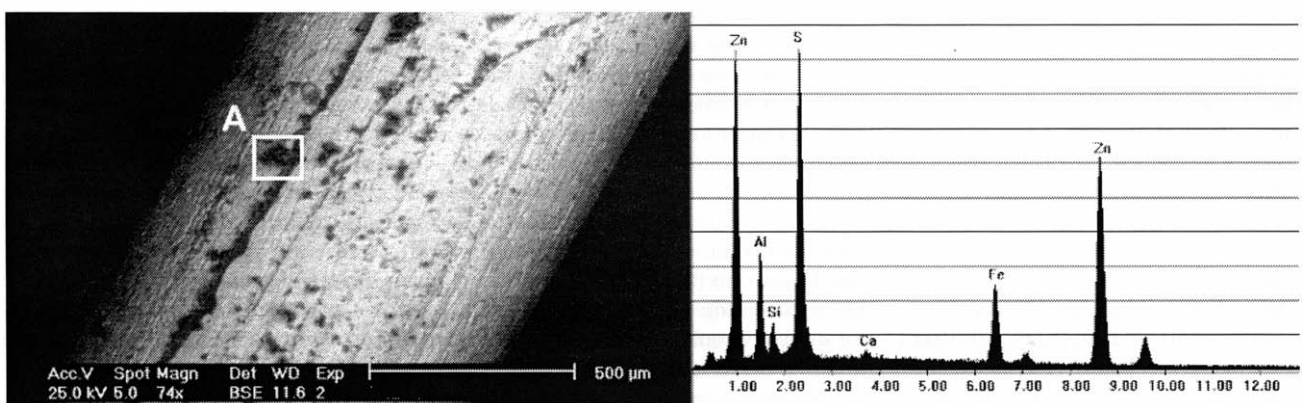


Figure 6 SEM/EDS analysis of the wire loop after burning of the matches/cigarette igniter at the right side of Figure 2. On the left: micrograph of a stick structure on the metal surface. On the left: EDS analysis on the area inside square A.

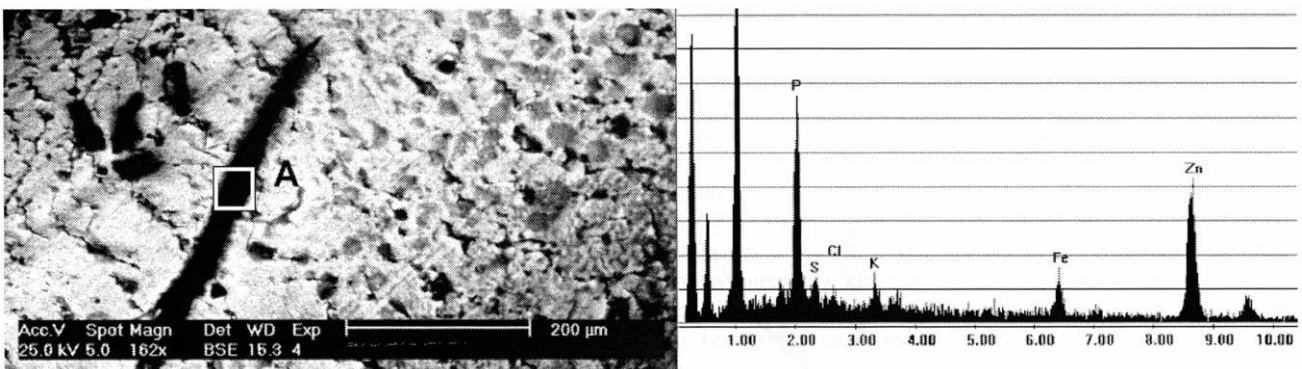
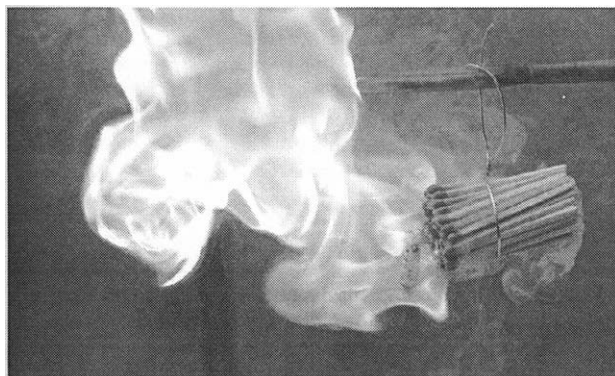


Figure 7 The little explosion of the matches/cigarette igniter.



the spectrogram, in addition to Fe and Zn, deriving from the metal, other elements are evident such as P, S, Cl and K.

The same analysis on the wire loop from the burned sulphur igniter gave the results depicted in Figure 5. The SEM micrography shows a lot of irregular spots on the metal surface, their composition, on the right side Figure 5, shows the metal elements and a high peak of sulphur.

Figure 6 shows the results of the wire loop from burned matches/cigarette igniter. On the metal surface, there were the same stick structures with the same composition observed on the wire loop samples. This igniter device employed eight minutes before the matches caught fire. The cigarette smouldering is self-sustained with a temperature ranging from 600 to 750°C, high enough to ignite the matches [30, 31].

Conclusions

The analytical data permit the depiction of a hypothetical scene. The accelerant presence together with a number of devices to start behindhand the fire suggest a deliberate action to produce heavy damage. A device like the laboratory matches/cigarette igniter might have been used. The eight minutes lag between the lighting of the cigarette and the blazing of matches could ensure the arsonists had the time to run away from the scene. They chose diesel fuel because it was coupled with the igniter action and it burnt only when started by the lit matches. In spite of the poor accelerant properties of diesel fuel, the temperature, higher than 34°C, together with the spreading on the dry vegetation, produced enough vapour to start the fire.

The high temperature of cigarette smouldering is strictly limited to a small area of the cigarette and requires a direct contact with flammable material, even if covered in diesel fuel, to start a fire. As to the igniter device used, the analytical results attributed their structure to the matches/cigarette type because of the presence, on the wire loops, of all the chemical components of matches. The stick structures observed and analysed by SEM/EDS were the residues of the little explosion produced by the ignited matches in Figure 7. The matches used are the most common in Italy and their chemical composition include 14 parts

of phosphorus trisulfide (P_2S_3) and 28 parts of potassium chlorate ($KClO_3$) together with other minor components. There is no evidence for the cigarette use but the experience of the fire investigators and the measured time lag are plausible. On the contrary, the sulphur igniter, despite the exact diameter correspondence (the measured diameter of the wire loop ring and sulphur tablet were both twenty-five millimetres), must be excluded because of the differences between the residues found on the wire loop samples and those detected on the sulphur igniter. Furthermore, when ignited, the sulphur tablet starts to burn immediately and goes on until the end without any shape variation. The hypothesis was that the burning tablet may decrease its dimension and in falling could start the fire of vegetation covered with the accelerant. The laboratory simulation did not give real evidence of this behaviour. It was able to start a fire on dry leaves, better still if covered in diesel fuel, but the tablet in burning did not decrease in size and it remained in its position inside the wire loop. This behaviour is due to the tablet composition which includes sulphur and an inert material which ensures a complete combustion of the sulphur without any drip or shape modification. This is necessary to avoid hazardous fire inside the treated barrels. Summarizing, it is possible to say that the woman was the unexpected victim of an intentional arson planned in every aspect, from the fire accelerant to the ignition devices, undoubtedly prepared elsewhere and before their use.

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